

CSC293 CS Improves 3D Printed Manufacturing FDM 3D Printing

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URCS

Outline

Printer Operation

Problems

Software Operation

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Operation

Filaments (common) or pellets (high throughput) of some polymer (plastic) are “melted” and extruded into layers.

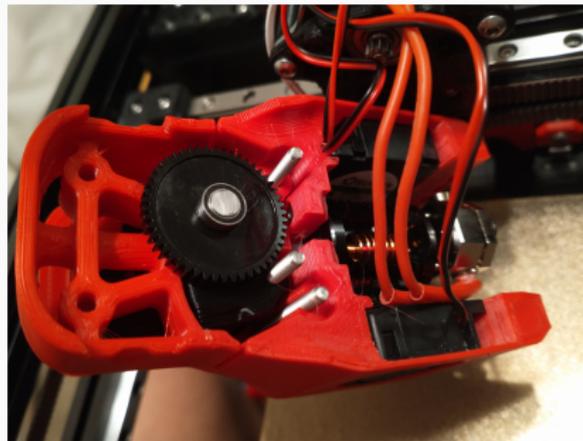
- PLA
- ABS / ASA
- Nylon
- PETG
- TPU

Material Print Settings

- Different polymers have different print settings
 - Bed plate temperature (70C for PLA, 100C for ABS)
 - Melt temperature (200C for PLA, 230C for ABS)
 - Chamber temperature (cool for PLA, 60C for ABS)
 - Print Speed (slow for TPU)
 - Flow rates (100% for PLA, 92% for ABS)
- All these settings are set in the Slicer

Extruder

- The extruder pushes the filament into the hotend
 - Or pulls it out
- Direct drive: extruder pushes directly into hotend
- “Bowden”: extruder is much further away (e.g. back of printer)
- On the printer you’re using:
 - Direct drive
 - Voron Clockwork 2
- User actions:
 - Increase/Decrease tension
 - Release Filament



Hotend

- The hotend heats the filament to its “melting” temperature
 - Usually 230 C for ABS
- Maintains a temperature gradient
 - Assisted by the hotend fan
 - If the fan fails, emergency!
- Maximum temperature and flow rate of hotend limits
 - What materials can be printed
 - How fast the printer can print
- No user actions



Nozzle

- Extrudes melted plastic under pressure
- Diameter of nozzle varies: common 0.4 mm
 - Fine detail – smaller diameter
 - Fast printing – bigger diameter
- Usually brass, but can be made of steel, and other materials
- Two popular standards V6 and MK8
- User action: Switching nozzles



Cooling

- Hotend fan (below)
 - always on when hotend is heating or above 50C
- Part cooling fan (above)
 - Mostly on for PLA, off or low for ABS
 - Usually switches on automatically for “bridges”
- No user actions

Source:

https://vorondesign.com/voron_stealthburner



Print Bed

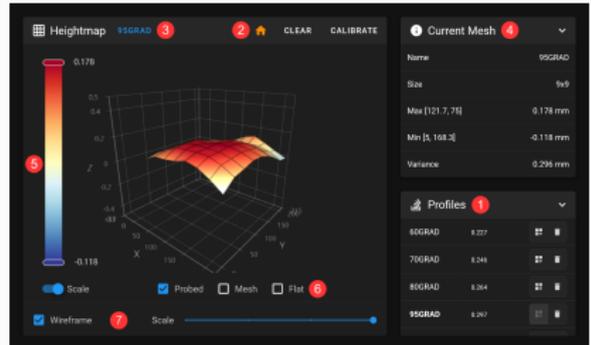
- Provides a level surface for printing
- Part must adhere to it when printing
 - And release after printing
- Achieved through:
 - heating the plate to glass temperature
 - using a removable PEI plate
- User actions:
 - plate removal and replacement
 - plate cleaning using soap (not IPA!)
- Always remove parts after bed has cooled down to around 50C
 - They should pop out easily without needing PEI plate to be removed.

Enclosure/Chamber

- Maintains chamber temperature
 - Reduces warping in ABS
 - Inhibits cooling for PLA!
- Keeps pollutants inside
 - Microplastics
 - VOCs

Positioning

- Homing: Print head locates a known position along X, Y, and Z axis
 - Probe: Print head locates print bed
- Z-tilt: Print bed is leveled so it is level wrt to print head
- Bed mesh: Records bed imperfections and adjusts while printing



General Warnings

- Burns
- Cuts
- Fumes
- Electric shocks

Machines are replaceable, your body parts are not.

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First Layer

- The first layer is the layer of plastic directly on the print surface
- Printed slower compared to the rest
- Common problems:
 - Partial adhesion (cancel and reprint)
 - Too less adhesion (cancel, add Skirt, Brim, Raft, and reprint)

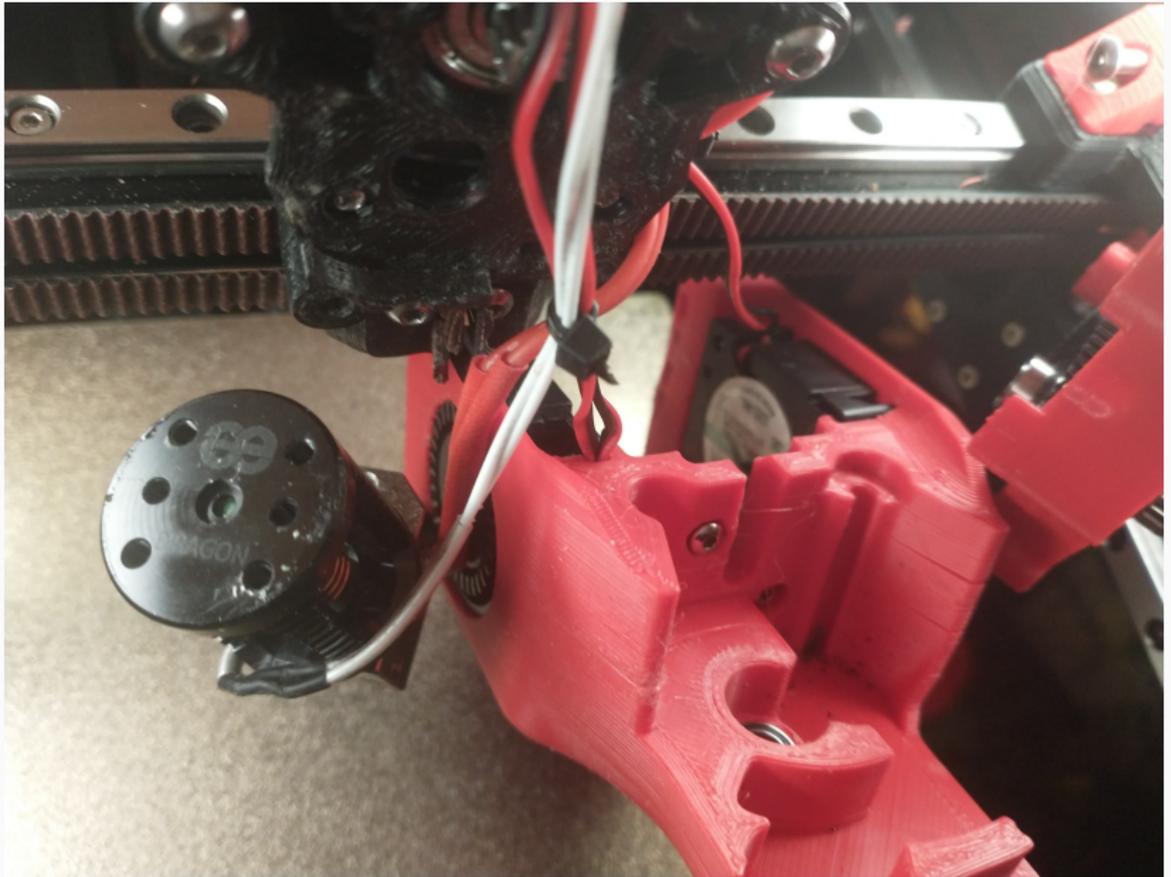
Warping



Warping – contd

- Parts of the print pull themselves off the surface (usually at the edges)
 - Uneven cooling
- Worst case: part topples while printing
- Bad case: part is warped and can't be used
- Good case: part has warps, but is functional
- Ensure:
 - Chamber is heated before printing
 - Cooling is not too much (esp. for ABS)

Clogs



Clogs (contd.)

- Filament jams inside cool part of hotend preventing extrusion
- Various methods, almost all involving dismantling the print head
- No specific cause, random occurrence
 - Except for “heat creep”, when the hotend fan is insufficient

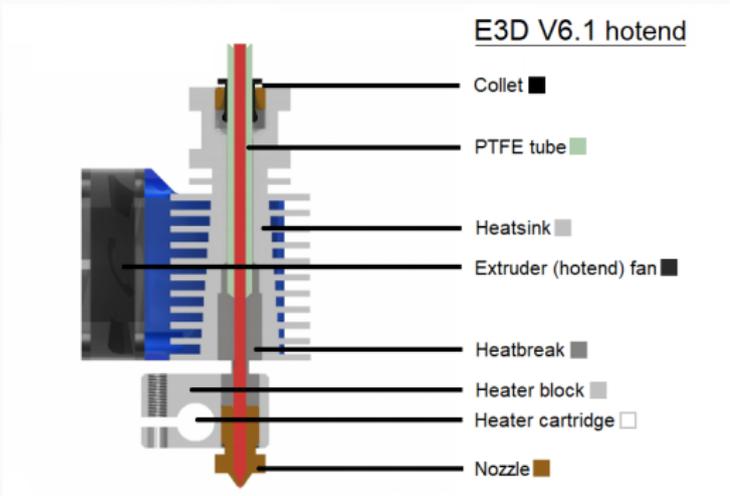
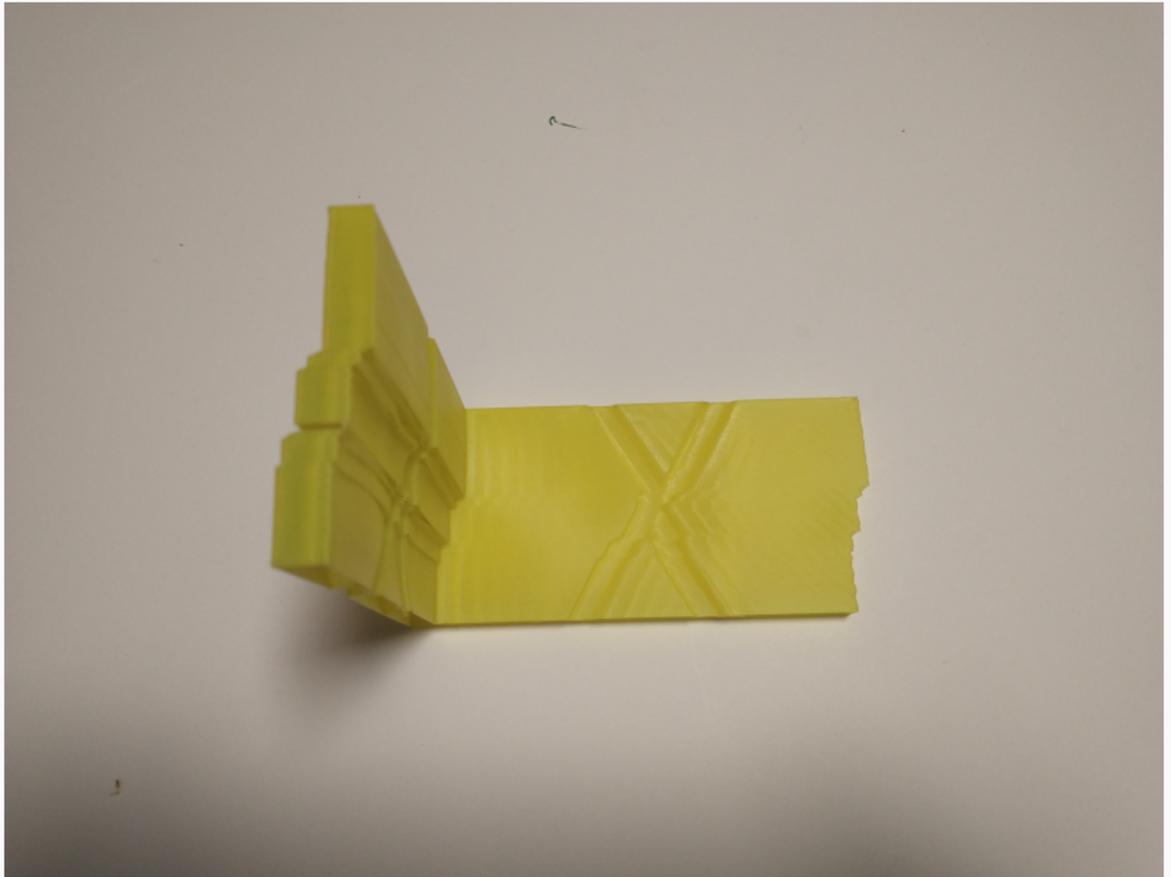


Image source: https://help.prusa3d.com/article/extrusion-stopped-mid-print-heat-creep_1948

Layer Shifts



Layer Shifts – contd.

- Printer is open-loop
 - It does not monitor its position continuously
- Thus, it can lose track of its position
 - Usually due to the print head hitting an object (e.g. toppled object)
 - Or due to poor construction (e.g. too short drag chains)
 - Many others
- This causes layers to shift during printing

Spaghetti



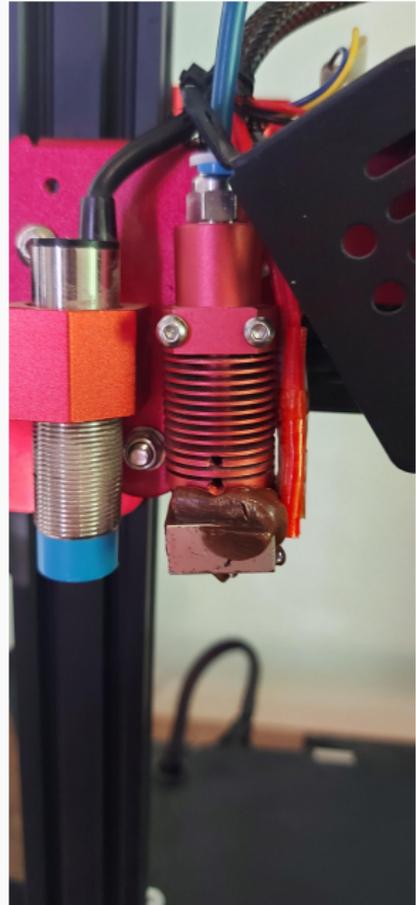
Spaghetti (contd.)

- Filament is extruded into free space instead of on top of previous layer
- Might be due to toppled object, layer shift, etc.
- Causes buildup of spaghetti, blobs, etc.

Blobs

- Blobs usually due to incorrect nozzle tightening
 - Causing leaks
- Also can happen if parts of filament attach themselves to nozzle and accumulate
 - This is what the silicone sock should prevent

Source: Reddit



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Connecting

- Printer hosts a web server running Mainsail, a web-based UI
- Printer has a touch screen attached to it that runs KlipperScreen
 - Fingers work, but prefer a stylus

Mainsail

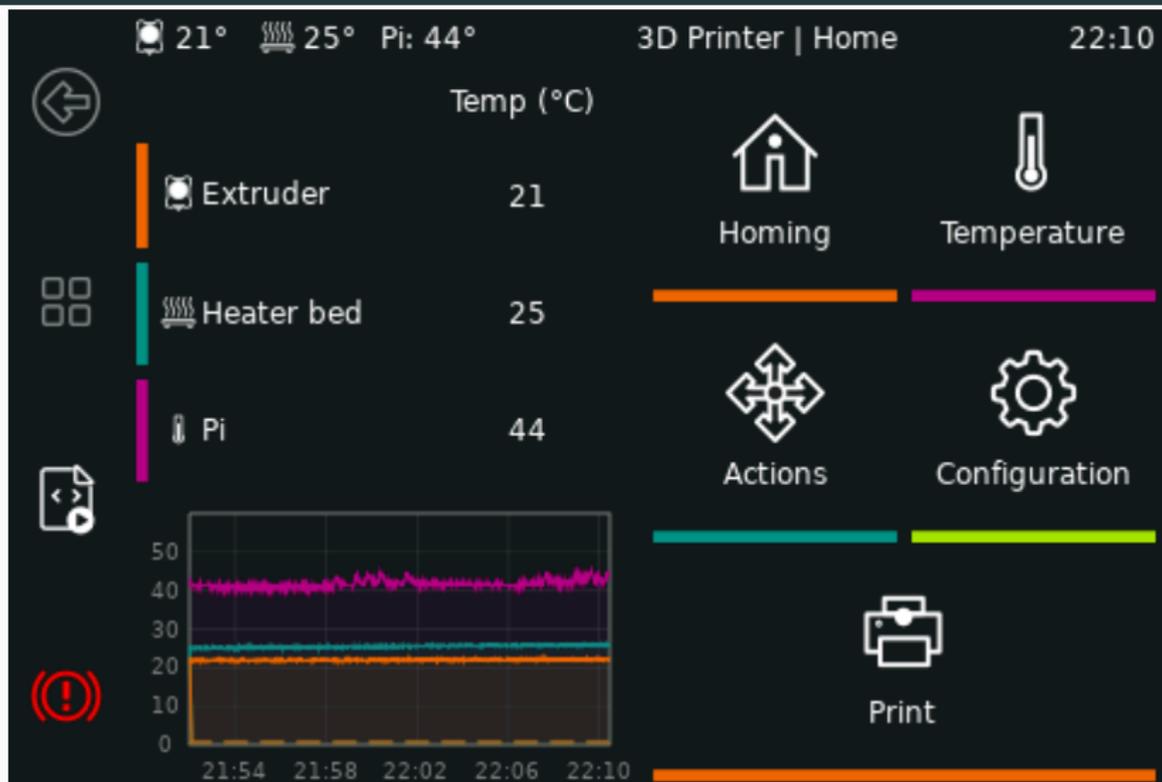
The screenshot displays the Mainsail web interface for a printer (V2.347). The interface is divided into several panels:

- Dashboard:** Shows "0% Printing" with a 3D model of a teal cube. Below the model, there are sections for "STATUS", "FILES", and "JOB QUEUE (0)". The status section includes fields for Speed (0 mm/s), Flow (0.0 mm/s), Filament (0.00 mm), and Layer (0 of 125). The estimate section shows a total time of 0:01:29.
- Toolhead:** Displays the position in absolute coordinates: X: 125.00, Y: 125.00, Z: 55.000. It also shows Z offset values: 0.000, +0.001, +0.003, +0.05.
- Temperatures:** A table showing current and target temperatures for various components:

Name	Now	Current	Target
Extruder	5%	151.4°C	150 °C
Hotend	100%	42.4°C	100 °C
Chamber	off	16.7°C	0 °C
Bed Corner		26.4°C	
M03		26.4°C	
M03 Manual		25.5°C	
M03 Toolhead		46.2°C	
BM		34.2°C	
- Webcam:** Shows two camera feeds of the printer's nozzle.
- Console:** Displays a list of G-code commands and their execution times, such as "G1 Z10.00" and "G1 X125.00".

Source: <https://docs.mainsail.xyz/>

KlipperScreen



Source:

<https://klipperscreen.readthedocs.io/en/latest/>

Emergency Shutoff

- Shuts down any printer activity
- Switches on the hotend fan

Exclude Objects



- If the “plate” contains multiple objects, you can individually cancel objects

References

- Niel Rosenberg, *Designing 3D Printers: Essential Knowledge*
- The Prusa Knowledge Base, even though it's specific to Prusa printers